FORECASTING FUEL DEMAND IN INDIA TRANSPORTATION SECTOR USING POOLED CROSS SECTION TIME SERIES APPROACH FOR MODELING CAR OWNERSHIP

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Abstract: Motorization in Asia is soaring in step with rapid growth in incomes. Even though the car population is still low in countries like China, India, or Indonesia, escalating number of vehicles is following GDP growth. This quick growth in car ownership may represent a significant implication on road transport fuel demand. This paper forecasts the demand for transport fuel in India. For this purpose, econometric models based on time series data are generated for specific factor affecting demand: car ownership.

So, firstly the econometric car ownership model was attempted in this study for projecting future car stock in India based on cross section time series technique. The car stock is modeled by using three models, which are the logistic, quasi-logistic and Gompertz curves. However, due to the size of India car fleet, these models were modeled by using pooled data of seven Asian countries (Japan, China, S. Korea, Thailand, Indonesia, Malaysia, and India). Then, a set of fuel consumption scenarios were developed in order to make forecast until 2030. These scenarios were generated by taking into consideration car stock, fuel efficiency and the average distance traveled in India.

Keywords: transport fuel modeling, car stock projections, Gompertz function, and quasi-logistic function.

1.Background

The liberalization of India economy promises a faster rate of growth of the economy reaching around 6.8% annually in the recent years (US Energy Information Administration (EIA), 2006). India's growing economy has witnessed a rise in demand for transport and services by around 10 percent a year (The World Bank, 2006). For the most part, this fast economic growth has brought a great challenge for the transport sector. Around the world, transportation relies on oil for almost all its fuel, and accounts nearly half of oil consumption. The coming trend in oil demand worldwide over the past decade has showed no signs of decrease. Besides, the total vehicle population attained 17.4 million in 2002 with an annual growth rate of 9 % during the 1990s (Dargay et al., 2006). The question is then how this country will be able to meet the increased demand for transportation fuel driven by increased economic activities and high population growth.

Transportation is an essential requirement for a society's development and improvement of people's life.

Macroeconomic facts about India's transport are indeed impressive, roads are the principal mean transportation and they share by almost 90 % of the country's passenger traffic and 65 % of its freight. India has a very dense highway network (0.66 km of highway per square kilometer of land) similar to that of the United States (0.65). In India, the share of the transport sector to total GDP in 1997 was about 4.4, contributed primarily by the road transport sector (The World Bank, 2006).

Recently, India is ranked the world's sixth largest oil consumer after the US, China, Japan, Russia and Germany (Bp Statistical review, 2006). Besides, India's domestic oil production capacity is limited. Consequently, India is a net oil-importing country and the amount of imported oil reached 80 million tons in 2005 (Bp Statistical review, 2006), accounting for 70% of total oil consumption. Future oil consumption in India is expected to show strong growth (3% annually), to 154 million tons by 2010, from 125 million tons in 2005 (US Energy Information Administration, 2006). A major cause of the increase in India oil consumption can be attributed to the rapid growth of the transportation sector leading in a higher growth in petroleum products. The issue of estimating this demand is of utmost importance in addressing India's future energy policy and in affecting world oil market. The government has opened the domestic refining sector for private investment to cope with challenges facing meet the increased demand for transportation fuel driven by increased economic activities and high population growth.

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The government has opened the domestic refining sector for private investment to cope with challenges facing petroleum products consumption. Nowadays, the refining capacity of 127.37 MM TPA has almost completely eliminated the need to import petroleum products in the short term.

$$\frac{812 \; vehicles}{1000 \; population} \; in \; 2002$$

Compared to the US fleets (), India's vehicle fleets ($\approx \frac{17 \; vehicles}{1000 \; population}$)

are in their infancy, however it is growing with an annual growth rate of 9% where in the US the vehicle fleets progress only at 2,8% annually. Taking into account both India population increase and its economic growth, the number of vehicles in India in the coming decades will soar rapidly and as result it will have considerable effect on India oil consumption. Hence, this sector can make worse import oil bill by demanding huge petroleum consumption. As a result, car ownership modeling for countries like India or China has a great impact on their fuel demand evolution in the future.

2-Overview of the transport sector in India

India is ranked 2[sd] in the world after USA in terms of transport network, encompassing 3,3 million kilometers (km) of roads. National Highways, spanning about 49,600 km throughout the country, are the important mean of transportation by satisfying about 40 % of the total road transport demand. The road transport is contributing about 80% in passenger traffic and about 50% in freight traffic compared to all other modes.

Basic Road Statistics, Ministry of Road Transport and Highways, India.

India's Transport Sector: The Challenges Ahead, the World Bank Group, 2002.

The Ministry of Petroleum & Natural Gas

Basic Road Statistics, Ministry of Road Transport and Highways, India.

India's Transport Sector: The Challenges Ahead, the World Bank Group, 2002.

Such a tremendous contribution of road transport can be attributed to a rapid growth in the population of vehicles. The growth rate was the highest for two-wheelers (11% per year), which constituted more than 70% of total vehicles in 2003. Besides, the transport infrastructure has expanded considerably over the last decades in order to maintain economic growth (figure 1).

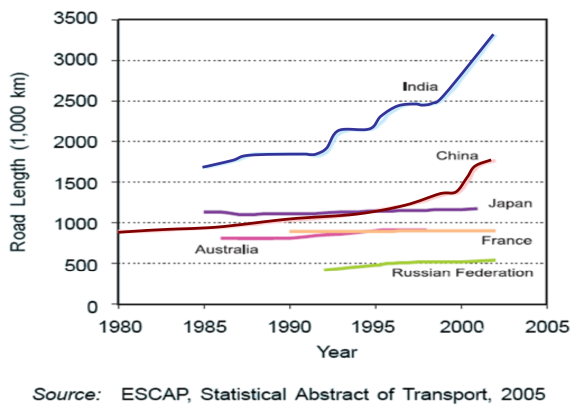

Figure 1: Road length in selected countries (1980-2003)

This sector comprises 17,4 million of vehicles and 47,5 million of motorcycles (two wheelers), which consume a half of petroleum products. About 40.71% of the total petroleum products sales went into the transport sector in the form of HSD (high speed diesel) and gasoline during 2003/2004. In 1970-71, 38.3% of the transport sector's energy usage came from petroleum products; this ratio went up rapidly to 82.1% by 1986-87 and to over 95% in recent years.

3-Methodology

The econometric fuel demand model is based on car ownership model combined with other factors dealing with the transportation sector.

Basic Road Statistics, Ministry of Road Transport and Highways, India.
Petroleum pricing in India, The Energy and Resources Institute TERI, 2005.

The development of this model is based firstly on literature review in order to select the key variables generally used by others studies. Then, data referring to these variables were collected. Finally, the outputs of the model were used to draw a number of scenarios of future fuel demand.

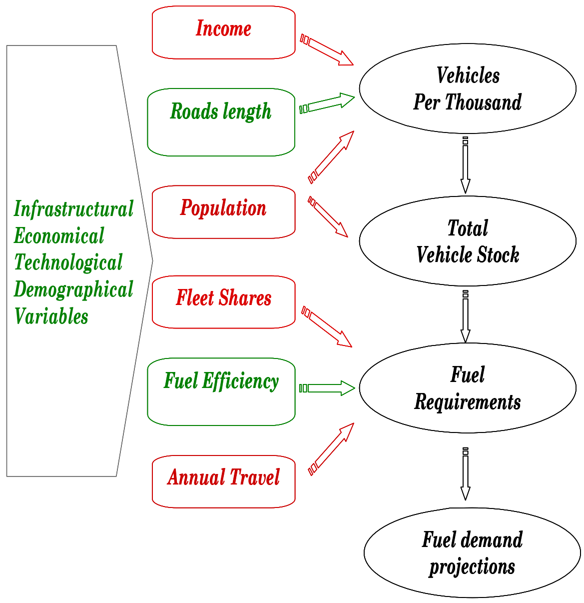

Figure 2: Structure of fuel demand Modeling

Total demand for transport fuel (F) is defined as the product of vehicle stock (C) by mean driving distance per car per year (U) divided by car efficiency eff (liter consumed per kilometer driven), (Dargay et al., 1997, Medlock et al., 2002, He et al., 2006 and Storchmann, 2005).

$$\begin{aligned} F &= C * U * eff \\ &= C * I \end{aligned} \quad (1)$$

Where: F: is the fuel consumption (million tons per year).

C: is the number of cars or vehicle stock

U: is the annual utilization per car (km/year)

eff: is the average fuel efficiency (liter /km)

I: fuel intensity (liter/year).

4-Car Ownership models

The Figure 2 illustrates the S-shape form of per capita vehicle ownership as a function of per capita income, revealing that there is a saturation level near which vehicle stock is no more influenced by per capita income changes.

For high-income countries (USA, Japan and Germany) that are approaching saturation levels, the graph has a curvature form before reaching the saturation levels. Moreover and for low-income countries (South Korea) the graph has a curvature form after being horizontal and low, which is known as take-off zone. Consequently the ownership car per capita is depicted by models offering two curvatures at low and high incomes and a saturation level. Several authors have attempted to propose the forecast model by adjusting the relationship between car ownership and income using a variety of nonlinear methods. For instance, Dargay et al. (1997) use a Gompertz function, Ögüt (2004) uses both Gompertz and logistic function, and Button et al. (1993) use a quasi-logistic form. The following sections present some of the non linear models found in the literature.

4.1-Aggregate Car Ownership Forecasting Models

These models use aggregate time-series data to estimate the equation 3 where the time is the only independent variable. This approach was introduced by Tanner (see: Ögüt, 2004) to fit the trend of car ownership demand as S curve. The report of OECD Road Research group combines these models into (Han B., 2001):

$$C = \frac{S}{\left[(1+\frac{k}{m}(1+\frac{at}{n})^{-n}\right]^{m}} \quad 2$$

With all parameters are positive and S represents the saturation level (figure 2). Different forms of models can be derived given specific values to m and n:

Logistic: m = 1, n = ∞ $C = \frac{S}{1+e^{at}}$

Gompertz: m = ∞, n = ∞ $C = Se^{ke^{at}}$

Power: m = 1 $C = \frac{S}{1+k(1+\frac{at}{n})^{-n}}$

The drawback of these models is the use the time as only independent variable to substitute social and economic factors influencing car ownership levels. This largely limits the usefulness of this approach. Tanner has introduced a logistic model, then he has modified it by adding the other variables of the income and the

$$C = \frac{S}{1+e^{at+b\ln(i)+c\ln(p)}}$$

motoring costs as, where i is the per capita income, p is motoring costs; a, b, c, and d are model coefficients. Also, he proposed the power function defined as:

$$C = \frac{S}{1+(a+b\,t+c\,\ln(i)+d\,\ln(p))^{-n}}$$

Aggregate Economic Models

Button et al (1993) adopted the equation 4 as the model of car ownership level by including a set of social and economic variables Xi rather than only the time. Using quasi-logistic approach, this model can be described as:

$$C = \frac{S}{1+e^{-a}X_1^{-b1}X_2^{-b2}\ldots X_n^{-bn}} \qquad (3)$$

$X_1, X_2, \ldots, X_n$

Where is a set of socioeconomic variables; a and b are parameters. By replacing time by these variables button work made a step forward compared with previous models.

Several authors have effectively demonstrated the utility of the Gompertz function for simulating car stock using per capita income as independent variable to generate future forecast (Dargay et al., 2006; and Ögüt, 2004).

$$C = S\,e^{\alpha\,e^{\beta\,GDP_t}}$$

$$or\ \ln(C) = \ln(S) + \alpha\,e^{\beta\,GDP_t}$$

C denotes the long-run equilibrium level of vehicle ownership, and GDP denotes per-capita income.

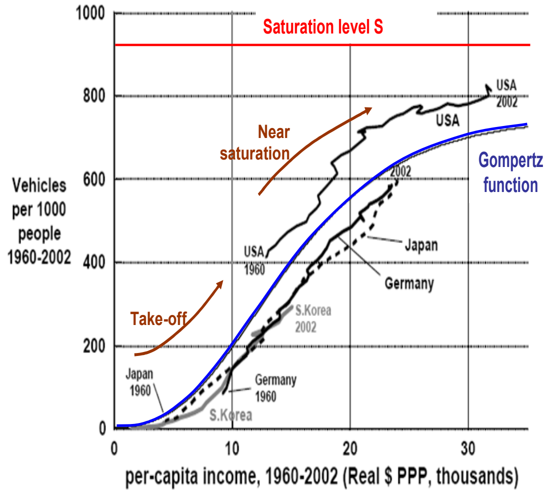

Figure 3: Vehicle Ownership and Per-Capita Income

Figure 3 illustrates per capita car stock as a function of GDP per capita for a group of countries at different levels of development. We can find out from the graph three stages in the evolution of Gompertz function.

First, Vehicle ownership increases slowly at the lowest levels income, and then it grows faster at middle-income levels before reaching finally saturation at the highest levels of income. These stages are described

S, α and β

by the coefficients denoting saturation level and the curvature shape of the function. However the major limitation of these non linear models is that they require an assumed saturation level before running the cross section regression. This may lead to significant forecast error due to the fact that the estimation curvature parameters depend heavily upon the assumed saturation level (Medlock et al., 2002).

Dargay, Gately, and Sommer, (2006), "Vehicle Ownership and Income Growth, Worldwide: 1960-2030".

4.3: India car ownership modeling

Different functional forms that can describe the relationship between per capita India vehicle ownership and per capita income are used in our study—for instance: the logistic, quasi-logistic and Gompertz functions. The preference for a specific functional form is based on the goodness of fit of the processed data since there is no theoretical basis for choosing one form over the other (Dargay et al., 1997). The model is estimated on the basis of time series data for some Asia countries (India, Indonesia, Malaysia, Thailand, China, Japan, and Korea) covering the time period from 1971 to 2002 (appendix A).

$$\underline{Gompertz}: C = S\, e^{\alpha e^{\beta\, Income}} \text{ or in a linear form:}$$

$$log(log(\frac{S}{C})) = log(-\alpha) + \beta * income \qquad (5)$$

$$\underline{Logistic}: C = \frac{S}{1+\alpha\, e^{\beta\, Income}} \text{ or in a linear form:}$$

$$log(\frac{S-C}{C}) = log(\alpha) + \beta * income \qquad (6)$$

$$\underline{Quasi-logistic}: C = \frac{S}{1+\alpha\, Income^{\beta}} \text{ or in a linear form:}$$

$$log(\frac{S-C}{C}) = log(\alpha) + \beta * log(income) \qquad (7)$$

Our first attempt is to estimate model parameters for each country individually by applying ordinary least squares (OLS) linear regression. It appears that the saturation levels obtained differ considerably between the countries (table 1). Besides, these levels can be summarized into three intervals: greater than 0.700 for Japan and S. Korea; below 0.100 for china, India and Indonesia and in between for Thailand and Malaysia. In addition, saturation levels (measured by per capita vehicle ownership) for china, Indonesia and Malaysia (0.016, 0.024 and 0.222 respectively) are underestimated by the regression compared to those registered in the year 2002 (0.017, 0.029 and 0.240 respectively); and they are very far from the real asymptotic saturation levels since these countries are only in the takeoff region (figure 3). Consequently it is not sensible to estimate the upper end of the curve by only the low income and car stock countries or the lower end of the curve on the basis of only high income (and car ownership) countries, except data were available for a long range.

Table 1: Estimated Gompertz parameters for selected Asia countries

(See Appendix B)

Many authors have used time series cross section approach; regrouping all countries together when estimating the car stock models (Dargay et al., 1997; Button et al.1993). However, some of them have employed the same saturation level for all countries but with different curvature parameters a and b. This assumption does not constrain saturation to be reached at the same income level, however varying a and b values in the estimation allow the shape of the curve and the rate of increase towards saturation to differ for the various countries. Moreover the pooled data method is chosen because we are interested to reflect a common development pattern. By imposing common saturation level across countries, future paths of developing nations may be mapped by the existing paths of industrialized nations.

Since the estimated saturation level for Japan is 0.785, we have supposed that the saturation level used in the pooled time-series cross-section approach is greater than this value. Several regressions were conducted by varying the saturation level S from 0.800 to 0.950 in order to achieve the best fit (measured by adjusted R^2) of the data. The resulting estimates are shown in the appendix B. A total of 21 regressions were made (7 supposed levels of saturation multiply by the 3 previous equations).

All the estimated coefficients are statistically significant and of the expected signs: α and β are negative. From the Adjusted R^2, we see the models explain the data very well; however, it is little bit difficult to choose the appropriate S since all estimated R^2 are very high. The value 0.850 represents the preferred saturation level S by which R^2 is at its maximum for Gomperts and quasi-logistic functions (0.994 and 0.995 respectively).

Hence, for the remaining of this study the saturation level is assumed to have the value of 0.850. The following figure shows the EVIEWS software results for the Gompertz, logistic and quasi logistic function when S equals 0.850. Both Student test and Fisher test were satisfied, which means that the coefficients are statistically significant.

Figure 4: India car ownership projection

(see Appendix B)

Figure 5: pooled time-series cross-section output for the selected models with saturation level S=0.850

(see Appendix B)

The models for India car stock are as follow:

$$C = 0.850\, e^{-8.273\, e^{-0.334\, \text{Income}}},$$

$$C = \frac{0.850}{1 + 1909.428\, e^{-1.668\, \text{Income}}} \quad \text{and}$$

$$C = \frac{0.850}{1 + 409.638\, \text{Income}^{-2.637}}$$

This plot compares the actual India car stock with the model estimates, over a long range of GDP per capita. We can notice from the graph that logistic function overestimates the car stock compared to Gompertz and quasi-logistic function. Moreover it has a vertical increase where the saturation level will be reached only when the India GDP per capita rises from 3000 to 5000 $ PPP.

However, the Gompertz and quasi logistic functions have a reasonable rise of car stock which will be as twice as 2002 value (0.017) when GDP attains 3000 $ PPP. These two functions have nearly the same lower curvature forms but the upper ones differ considerably, and the saturation level will be reached at two distinctive GDP values 20 000 and 35 000 $ PPP.

Other variables influencing car stock

The assumption used above, that car ownership progress is linked only to per capita income which is considered as the surrogate of other socioeconomic variables influencing the growth of car stock. These socioeconomic variables encompass costs (possessing and operating costs), age structure of the population, population density, urbanization, and road density. In this section we analyze the impact of road density per capita and income on India car stock and especially how road density is going to affect the shape of the s curve.

Road Density

Over the past decade, there has been growing interest in integrating transportation growth and its infrastructure planning, based on recognition that there is a mutual influence between road network and transportation activity. The availability of a good network of roads would encourage vehicle ownership; however the lack of good roads would discourage ownership.

Similar to our argument with respect to the car stock we assume that car possession is related to per capita income and pre capita road density. The specification of the equations estimating the car stock look as follows:

$$C = S\, e^{\alpha e^{\beta 1\, Income + \beta 2\, road}} \text{ or in a linear form:}$$

$$log(log(\frac{S}{C})) = log(-\alpha) + \beta_1 * income + \beta_1 * road \quad (8)$$

$$C = \frac{S}{1+\alpha\, income^{\beta 1} road^{\beta 2}} \quad \text{or in a linear form:}$$

$$log(\frac{S-C}{C}) = log(\alpha) + \beta 1 * log(income) + \beta 2 * log(road) \quad (9)$$

In figures 6 and 7 we depicted India car stock by means of Gompertz and quasi logistic functions estimated under the assumption that saturation level remains equal to 0.850. The car stock forecasts show the same trend as in the previous graphs, the quasi-logistic function underestimates the vehicle ownership compared to Gompertz function even by adding road density as the second independent variable. During the last five years, the per capita GDP and per capita road density have progressed annually by 3,34% and 0.67% respectively, then we have assumed that the per capita GDP grows by the same cadence (3.34% annually) and four scenarios are generated for per capita road density. These scenarios illustrate the effect of road infrastructure on S curve when the per capita road density rises at the following rates: 0.4%, 0.67%, 1.00% and 2.00%.

As can be seen in these Figures, curves related to function including the two independent variables (income and road) are all beneath that with income as independent variable. At $ 10 000 income the car stock estimated by 0.4% road growth rate curve is 0.505 much lower than that given by the curve having only income as independent variable (0.635), but the two curves have the same lower and upper ends.

Figure 6: effect of road network evolution on India car ownership by using Gompertz function

(see Appendix B)

Figure 7: effect of road network evolution on India car ownership by using Quasi-logistic function

(see Appendix B)

Validation of the models

The outputs of the various models appear statistically significant with adjusted R^2 greater than 90%. However, the efficacy of the models depends on the forecast accuracy which can be determined by computing the bias between the estimates and actual data. Hence, several regressions were done by suspending the last, the two last or the three last observations; and by comparing the estimates to observations taken away.

Table 2: Estimated Gompertz parameters for selected Asia countries

(see Appendix B)

As a test, the observations for the test period are removed from the time series data and the models are again generated. Then these models are evaluated for ex post forecast accuracy by assessing the mean absolute deviation (MAD) between estimated values and the observed ones. The test calculations are presented in Table 3. As can be observed, the MAD for Quasi-logistic model are lower than those of Gompertz model, but both are relatively higher compared to observed data. This is due to the fact that India car stock is very low to the saturation level employed.

Fuel requirements

Based on the equation 1, the fuel intensity per car includes two parts: the use of the car stock and the fuel efficiency. While, similar to the car stock, the car use is sensitive income and fuel prices, the fuel efficiency represents improvement in car consumption on long term basis. This could be worthy of applying regression to estimate these parts, which would require long past information on the fuel efficiency and mean distance traveled by car. These data are not available. Thus, we can combine with information on average annual vehicle use, vehicle fuel efficiency and assumptions on their future changes to generate fuel consumption forecasts. According to Dargay et al (1997), India car use is 15 km annually with a fuel efficiency of 13 liters per 100 km decreasing by 0.5% per annum in the future. Combining these data with future car stock, India fuel demand is depicted by the following figure.

Figure 8: Vehicle fuel demand forecasting

(see Appendix B)

Since India vehicle fleet is in the take-off zone, it will be nearly four times greater in 2015 (66 million vehicles) leading to predict fuel consumption of 100 000 million liters, three times more than that registered in 2002 (34 045 million liters). The red curve represents the worst case in India fuel consumption which my reach 100 000 million liters (273 ml/d) in 2010.

Conclusion

In this paper, econometric models have been developed for fuel demand in India transportation sector with an aim of generating forecasts in the coming decades. Vehicle ownership has been treated as an independent sub model within fuel demand modeling, influenced principally by socioeconomic characteristics of countries. Recent modeling efforts have incorporated effects of per capita income to improve the practicality of the vehicle ownership models.

Pooled data approach was used to analyze the time series data covering seven Asian countries from 1971 to 2002. Besides, three functions (Gompertz, logistic and quasi-logistic) were modeled by this approach to depict the S curve shape of car stock evolution. Under the assumption that saturation level S is equal to 0.85, India car ownership has been projected by means of the previous functions and taking into consideration the growth of per capita income and per capita road density. Logistic model was eliminated since it has generated an unrealistic car stock growth with the restricted saturation level of 0.85. It is expected that India vehicle stock will be four times greater in 2015 than in 2002, increasing to nearly fifty million vehicles. Finally, our results suggest that significant increases in oil demand from the transport sector to fuel its car stock which is showing a strong growth in the approaching years. Without any breakthrough technology change, it is expected that petroleum products will fuel the transportation sector as before. This has the implications for oil market and oil producers in Middle East and North Africa (MENA) specially OPEC ME oil producers.

Appendix A

The table 2 summarizes the historical data for the countries covered in this study. Each country is represented by two columns showing per-capita GDP ($ PPP and per thousands) from 1971 to 2002, as well as car stock levels (defined as the number of cars divided by population).

Table 3: per capita GDP (PPP) and per capita car ownership for a set of Asia countries

Source: International Fund Monetary FMI

	India		Indonesia		Malaysia		Thailand		China		Japan		Korea	
	G_ind	car_ind	G_indo	car_indo	G_mal	car_mal	G_tha	car_tha	G_china	car_china	G_jap	car_jap	G_kor	car_kor
1971	1.029	0.002	0.833	0.003	2.512	0.031	1.673	0.010	0.565	0.001	11.242	0.179	2.540	0.004
1972	1.001	0.002	0.876	0.003	2.673	0.033	1.695	0.011	0.567	0.001	12.019	0.198	2.614	0.004
1973	1.009	0.002	0.938	0.004	2.904	0.038	1.814	0.011	0.598	0.001	12.804	0.220	2.885	0.005
1974	0.999	0.002	0.990	0.004	3.053	0.042	1.841	0.009	0.601	0.001	12.478	0.236	3.046	0.005
1975	1.068	0.002	1.023	0.004	3.013	0.046	1.877	0.013	0.631	0.001	12.702	0.250	3.191	0.005
1976	1.065	0.002	1.102	0.005	3.252	0.049	1.993	0.014	0.612	0.001	13.066	0.259	3.491	0.006
1977	1.119	0.002	1.170	0.006	3.427	0.053	2.127	0.015	0.637	0.001	13.508	0.273	3.782	0.008
1978	1.149	0.003	1.248	0.007	3.561	0.058	2.241	0.016	0.692	0.001	14.091	0.287	4.060	0.010
1979	1.063	0.003	1.307	0.007	3.738	0.067	2.308	0.017	0.726	0.002	14.737	0.304	4.281	0.013
1980	1.108	0.002	1.388	0.008	3.926	0.078	2.409	0.012	0.756	0.002	15.033	0.320	4.127	0.014
1981	1.157	0.003	1.468	0.009	4.097	0.084	2.478	0.016	0.789	0.002	15.337	0.332	4.326	0.015
1982	1.175	0.003	1.452	0.010	4.232	0.088	2.558	0.018	0.851	0.002	15.714	0.345	4.568	0.016
1983	1.235	0.003	1.540	0.011	4.388	0.096	2.665	0.024	0.931	0.002	15.972	0.358	4.983	0.020
1984	1.254	0.003	1.615	0.012	4.613	0.104	2.759	0.027	1.059	0.002	16.478	0.371	5.328	0.023
1985	1.294	0.005	1.641	0.013	4.418	0.108	2.819	0.030	1.175	0.003	17.124	0.384	5.617	0.027
1986	1.328	0.006	1.700	0.013	4.350	0.111	2.910	0.032	1.256	0.003	17.529	0.397	6.171	0.032
1987	1.362	0.006	1.752	0.014	4.468	0.112	3.133	0.037	1.373	0.004	18.208	0.411	6.782	0.039
1988	1.465	0.006	1.826	0.013	4.793	0.114	3.479	0.037	1.496	0.004	19.316	0.429	7.419	0.048
1989	1.529	0.006	1.952	0.014	5.104	0.119	3.880	0.041	1.535	0.005	20.249	0.448	7.792	0.063
1990	1.583	0.007	2.124	0.016	5.333	0.124	4.228	0.048	1.573	0.005	21.230	0.470	8.409	0.079
1991	1.558	0.008	2.289	0.017	5.770	0.135	4.540	0.049	1.696	0.005	21.850	0.488	9.094	0.098
1992	1.609	0.009	2.413	0.018	6.137	0.139	4.857	0.055	1.915	0.006	22.000	0.505	9.490	0.120
1993	1.654	0.009	2.545	0.018	6.468	0.129	5.190	0.063	2.150	0.007	22.005	0.518	9.910	0.142
1994	1.745	0.010	2.693	0.020	6.871	0.138	5.591	0.071	2.399	0.008	22.177	0.531	10.620	0.166
1995	1.842	0.010	2.858	0.021	7.335	0.149	6.074	0.078	2.624	0.009	22.544	0.544	11.452	0.188
1996	1.937	0.011	3.044	0.023	7.887	0.165	6.385	0.088	2.845	0.009	23.228	0.558	12.108	0.210
1997	1.986	0.012	3.138	0.024	8.270	0.182	6.235	0.097	3.066	0.010	23.596	0.570	12.596	0.227
1998	2.064	0.013	2.666	0.024	7.484	0.188	5.498	0.103	3.275	0.011	23.267	0.577	11.669	0.226
1999	2.170	0.014	2.649	0.025	7.753	0.200	5.674	0.109	3.477	0.012	23.245	0.582	12.849	0.239
2000	2.215	0.014	2.740	0.026	8.116	0.210	5.859	0.110	3.725	0.013	23.851	0.588	13.930	0.257
2001	2.263	0.016	2.798	0.027	7.966	0.223	5.933	0.118	3.976	0.014	23.899	0.594	14.261	0.273
2002	2.336	0.017	2.864	0.029	8.123	0.240	6.192	0.127	4.279	0.016	23.888	0.599	15.071	0.293

Appendix B

Table 4: Cross section time series regression outputs for different saturation level S

car_ownership=S*exp(α*exp(β*income))------Gompertz

Saturation level S		0.9500	0.9250	0.9000	0.8750	0.8500	0.8250	0.8000
alpha	India	-8.3653	-8.3431	-8.3205	-8.2973	-8.2734	-8.2490	-8.2239
	China	-7.1062	-7.0804	-7.0538	-7.0265	-6.9984	-6.9694	-6.9396
	Indonesia	-6.3307	-6.3059	-6.2805	-6.2544	-6.2275	-6.1999	-6.1715
	Japan	-4.4583	-4.5587	-4.6787	-4.8237	-5.0009	-5.2207	-5.4986
	S. Korea	-7.5627	-7.5635	-7.5654	-7.5685	-7.5730	-7.5791	-7.5870
	Malysia	-4.3034	-4.2859	-4.2681	-4.2503	-4.2324	-4.2143	-4.1963
	Thailand	-5.8183	-5.7985	-5.7783	-5.7577	-5.7367	-5.7153	-5.6934
beta	India	-0.3272	-0.3289	-0.3307	-0.3326	-0.3346	-0.3367	-0.3388
	China	-0.1452	-0.1460	-0.1467	-0.1475	-0.1483	-0.1492	-0.1501
	Indonesia	-0.1969	-0.1982	-0.1994	-0.2007	-0.2021	-0.2035	-0.2050
	Japan	-0.0920	-0.0951	-0.0986	-0.1025	-0.1069	-0.1119	-0.1176
	S. Korea	-0.1314	-0.1329	-0.1344	-0.1361	-0.1378	-0.1396	-0.1416
	Malysia	-0.1296	-0.1312	-0.1330	-0.1348	-0.1367	-0.1388	-0.1410
	Thailand	-0.1581	-0.1595	-0.1610	-0.1625	-0.1641	-0.1658	-0.1676
	R^2	0.993937	0.993984	0.994025	0.994057	**0.994074**	0.994070	0.994032

car_ownership=S/(1+alpha*exp(β*income))-------------Logistic

Saturation level S		0.9500	0.9250	0.9000	0.8750	0.8500	0.8250	0.8000
alpha	India	2131.5549	2076.0223	2020.4913	1964.9597	1909.4280	1853.8985	1798.3700
	China	1071.8421	1043.6777	1015.5118	987.3474	959.1822	931.0174	902.8523
	Indonesia	433.2921	421.9636	410.6347	399.3064	387.9781	376.6502	365.3223
	Japan	17.0321	17.0983	17.2210	17.4148	17.7001	18.1061	18.6751
	S. Korea	415.8393	406.4037	396.9923	387.6082	378.2544	368.9352	359.6549
	Malysia	45.6204	44.5124	43.4062	42.3019	41.1997	40.1001	39.0031
	Thailand	189.5483	184.7650	179.9831	175.2026	170.4239	165.6470	160.8720
beta	India	-1.6668	-1.6671	-1.6675	-1.6678	-1.6682	-1.6686	-1.6690
	China	-0.7931	-0.7932	-0.7934	-0.7935	-0.7936	-0.7937	-0.7939
	Indonesia	-0.8862	-0.8865	-0.8868	-0.8872	-0.8876	-0.8879	-0.8883
	Japan	-0.1387	-0.1417	-0.1450	-0.1487	-0.1529	-0.1577	-0.1632
	S. Korea	-0.3933	-0.3942	-0.3952	-0.3963	-0.3974	-0.3987	-0.4000
	Malysia	-0.3244	-0.3255	-0.3268	-0.3281	-0.3295	-0.3309	-0.3325
	Thailand	-0.5246	-0.5253	-0.5260	-0.5268	-0.5276	-0.5285	-0.5295
	R^2	0.984494	0.984612	0.984737	0.984871	0.985015	0.985169	**0.985334**

car_ownership=S/(1+alpha*income$^\beta$)-------------quasi-Logistic

Saturation level S		0.9500	0.9250	0.9000	0.8750	0.8500	0.8250	0.8000
alpha	India	457.8841	445.8230	433.7616	421.6999	409.6389	397.5775	385.5161
	China	432.7772	421.3501	409.9229	398.4958	387.0686	375.6414	364.2145
	Indonesia	201.6574	196.3296	191.0018	185.6741	180.3465	175.0187	169.6911
	Japan	1403.4503	1540.4194	1712.9786	1934.8518	2227.1522	2623.7189	3181.4934
	S. Korea	4187.6165	4108.0100	4028.9457	3950.4904	3872.7146	3795.7033	3719.5575
	Malysia	122.3626	119.7174	117.0815	114.4559	111.8421	109.2413	106.6552
	Thailand	265.6966	259.0541	252.4138	245.7759	239.1404	232.5081	225.8787
beta	India	-2.6356	-2.6360	-2.6365	-2.6371	-2.6376	-2.6382	-2.6388
	China	-1.4386	-1.4388	-1.4390	-1.4392	-1.4394	-1.4396	-1.4398
	Indonesia	-1.6212	-1.6217	-1.6223	-1.6229	-1.6235	-1.6241	-1.6248
	Japan	-2.4133	-2.4631	-2.5186	-2.5805	-2.6504	-2.7297	-2.8208
	S. Korea	-2.8163	-2.8220	-2.8281	-2.8345	-2.8415	-2.8489	-2.8569
	Malysia	-1.6847	-1.6901	-1.6959	-1.7020	-1.7086	-1.7157	-1.7232
	Thailand	-1.8821	-1.8844	-1.8868	-1.8894	-1.8921	-1.8950	-1.8981
	R^2	0.994654	0.994663	0.994672	0.994678	**0.994682**	0.994681	0.994674

Table 5: Estimated Gompertz parameters for selected Asia countries

	India	Indonesia	Malaysia	Thailand	China	Japan	Korea
S	0.025	0.024	0.222	0.234	0.014	0.785	0.714
Alpha	-9.500	-6.347	-6.572	-5.217	-4.701	-5.477	-7.702
Beta	-1.300	-1.325	-1.325	-0.294	-0.969	-0.119	-0.151
Adjusted R^2	0.953	0.989	0.967	0.958	0.974	0.987	0.995

Source: Authors Estimation using data 1971-2002, OLS method.

Gompertz

Dependent Variable: LOG(LOG(0.850/CAR?))
Method: Pooled Least Squares
Date: 08/03/06 Time: 22:08
Sample: 1971 2002
Included observations: 32
Cross-sections included: 7
Total pool (balanced) observations: 224

Variable	Coefficient	Std. Error	t-Statistic	Prob.
_IND--C	2.113051	0.037439	56.44042	0.0000
_CHINA--C	1.945675	0.018256	106.5752	0.0000
_INDO--C	1.828982	0.028713	63.69904	0.0000
_JAP--C	1.609610	0.044692	36.01559	0.0000
_KOR--C	2.024592	0.022008	91.99306	0.0000
_MAL--C	1.442758	0.030228	47.72951	0.0000
_THA--C	1.746879	0.025151	69.45603	0.0000
_IND--G_IND	-0.334612	0.024338	-13.74866	0.0000
_CHINA--G_CHINA	-0.148324	0.009007	-16.46777	0.0000
_INDO--G_INDO	-0.202073	0.014168	-14.26235	0.0000
_JAP--G_JAP	-0.106925	0.002383	-44.87051	0.0000
_KOR--G_KOR	-0.137781	0.002619	-52.61557	0.0000
_MAL--G_MAL	-0.136731	0.005486	-24.92440	0.0000
_THA--G_THA	-0.164090	0.006189	-26.51219	0.0000

R-squared	0.994074	Mean dependent var	1.040720
Adjusted R-squared	0.993707	S.D. dependent var	0.725695
S.E. of regression	0.057567	Akaike info criterion	-2.811262
Sum squared resid	0.695939	Schwarz criterion	-2.598034
Log likelihood	328.8613	F-statistic	2709.799
Durbin-Watson stat	0.329504	Prob(F-statistic)	0.000000

Logistic

Dependent Variable: LOG((0.850-CAR?)/CAR?)
Method: Pooled Least Squares
Date: 08/03/06 Time: 21:59
Sample: 1971 2002
Included observations: 32
Cross-sections included: 7
Total pool (balanced) observations: 224

Variable	Coefficient	Std. Error	t-Statistic	Prob.
_IND--C	7.554559	0.162415	46.51380	0.0000
_CHINA--C	6.866081	0.079199	86.69368	0.0000
_INDO--C	5.960949	0.124562	47.85544	0.0000
_JAP--C	2.873572	0.193882	14.82123	0.0000
_KOR--C	5.935567	0.095475	62.16876	0.0000
_MAL--C	3.718432	0.131134	28.35605	0.0000
_THA--C	5.138289	0.109109	47.09319	0.0000
_IND--G_IND	-1.668185	0.105582	-15.79996	0.0000
_CHINA--G_CHINA	-0.793606	0.039074	-20.31052	0.0000
_INDO--G_INDO	-0.887550	0.061464	-14.44005	0.0000
_JAP--G_JAP	-0.152912	0.010338	-14.79160	0.0000
_KOR--G_KOR	-0.397449	0.011360	-34.98638	0.0000
_MAL--G_MAL	-0.329450	0.023799	-13.84330	0.0000
_THA--G_THA	-0.527648	0.026850	-19.65169	0.0000

R-squared	0.985015	Mean dependent var	3.305155
Adjusted R-squared	0.984088	S.D. dependent var	1.979776
S.E. of regression	0.249737	Akaike info criterion	0.123648
Sum squared resid	13.09745	Schwarz criterion	0.336876
Log likelihood	0.151397	F-statistic	1061.865
Durbin-Watson stat	0.213781	Prob(F-statistic)	0.000000

Quasi-logistic

Dependent Variable: LOG((0.850-CAR?)/CAR?)
Method: Pooled Least Squares
Date: 08/03/06 Time: 21:56
Sample: 1971 2001
Included observations: 31
Cross-sections included: 7
Total pool (balanced) observations: 217

Variable	Coefficient	Std. Error	t-Statistic	Prob.
_IND--C	6.015276	0.043583	138.0173	0.0000
_CHINA--C	5.958602	0.028784	207.0128	0.0000
_INDO--C	5.194880	0.045073	115.2542	0.0000
_JAP--C	7.708479	0.316946	24.32114	0.0000
_KOR--C	8.261711	0.094266	87.64231	0.0000
_MAL--C	4.717088	0.119451	39.48969	0.0000
_THA--C	5.477051	0.075374	72.66468	0.0000
_IND--LOG(G_IND)	-2.637600	0.101907	-25.88249	0.0000
_CHINA--LOG(G_CHINA)	-1.439359	0.041531	-34.65725	0.0000
_INDO--LOG(G_INDO)	-1.623488	0.066623	-24.36831	0.0000
_JAP--LOG(G_JAP)	-2.650354	0.110185	-24.05377	0.0000
_KOR--LOG(G_KOR)	-2.841458	0.049289	-57.64932	0.0000
_MAL--LOG(G_MAL)	-1.708601	0.074423	-22.95794	0.0000
_THA--LOG(G_THA)	-1.892124	0.059208	-31.95733	0.0000

R-squared	0.994682	Mean dependent var	3.348781
Adjusted R-squared	0.994341	S.D. dependent var	1.972313
S.E. of regression	0.148365	Akaike info criterion	-0.915947
Sum squared resid	4.468450	Schwarz criterion	-0.697889
Log likelihood	113.3802	F-statistic	2920.690
Durbin-Watson stat	0.441018	Prob(F-statistic)	0.000000

Figure 9: pooled time-series cross-section output for the selected models with saturation level S=0.850

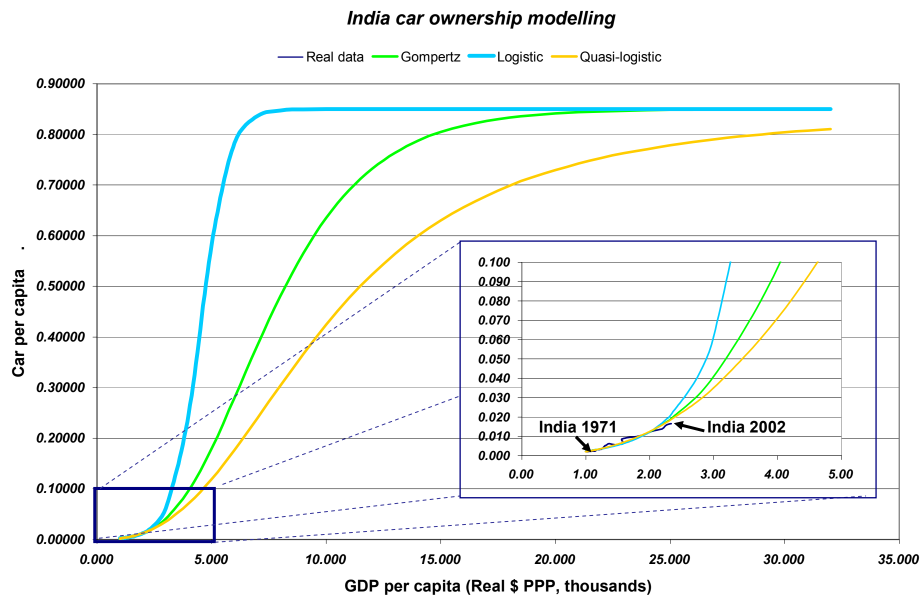

Figure 10: India car ownership projection

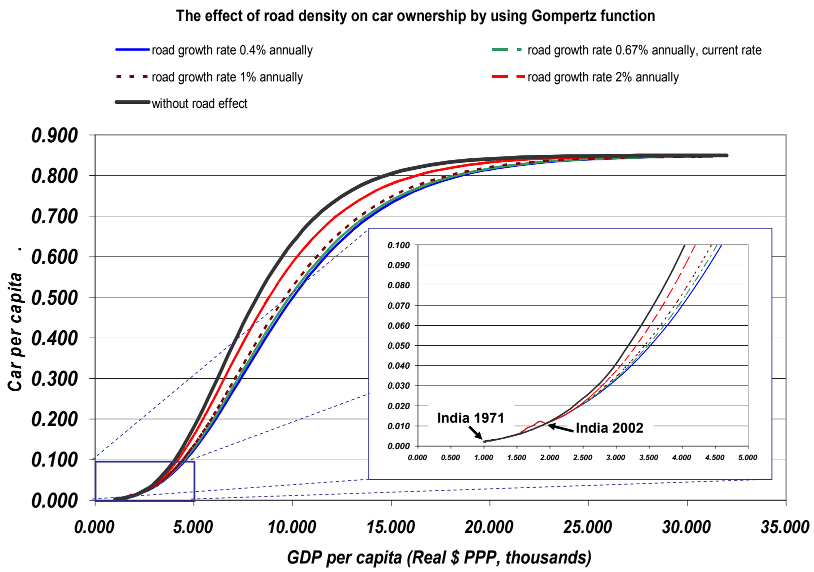

Figure 11: effect of road network evolution on India car ownership by using Gompertz function

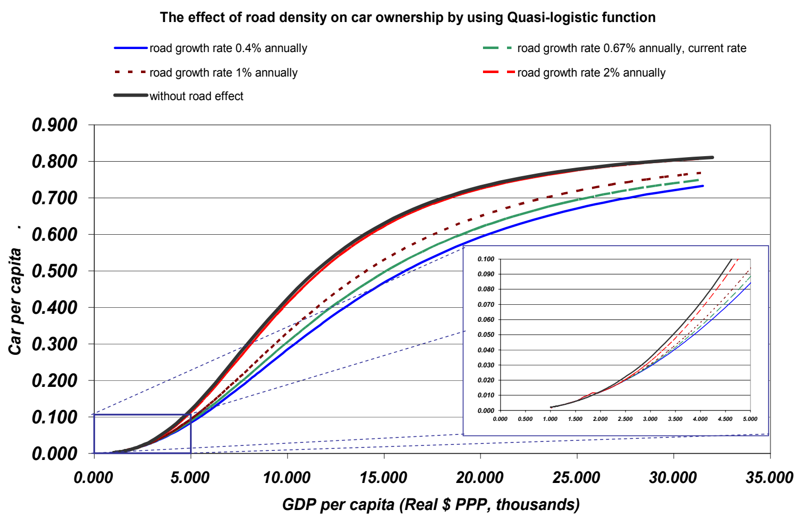

Figure 12: effect of road network evolution on India car ownership by using Quasi-logistic function

Table 6: Estimated Gompertz parameters for selected Asia countries

		Gompertz function				Quasi-logistic function		
Eliminating	year	2000	2001	2002		2000	2001	2002
the last three	Actual data	0.01435	0.01592	0.01655		0.01435	0.01592	0.01655
observations	Estimated data	0.018841	0.02014	0.02226		0.017317	0.018317	0.019923
	bias	-0.00449	-0.00422	-0.00571		-0.00296	-0.00239	-0.00337
	Mean absolute deviation	0.0048				0.0029		
Eliminating	year	2001	2002			2001	2002	
the last two	Actual data	0.01592	0.01655			0.01592	0.01655	
observations	Estimated data	0.019327	0.021329			0.01751	0.01900	
	bias	-0.003409	-0.004780			-0.00159	-0.00245	
	Mean absolute deviation	0.0040				0.0020		
Eliminating	year	2002				2002		
the last	Actual data	0.01655				0.01655		
observation	Estimated data	0.020752				0.018656		
	bias	-0.00420				-0.00210		
	Mean absolute deviation	0.0042				0.0021		

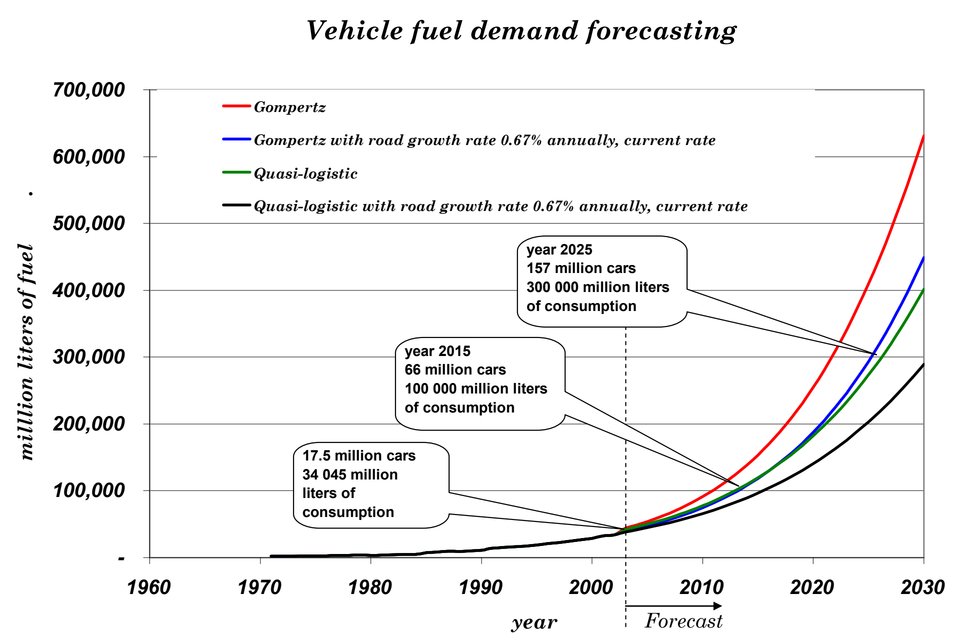

Figure 13:Vehicle fuel demand forecasting

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